Radiation Transmission-based Thickness Measurement Systems - Advancements, Innovations and New Technologies

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1. Introduction

Radiation transmission-based gauging systems (employing either natural or artificial sources) provide a unique means of non-contact thickness measurement. These systems have experienced a broad acceptance and been employed in a variety of flat rolled sheet product applications and processes, over the last 6+ decades. For a majority of this time, technological and processing speed limitations constrained the avenues and extent of new developments in this field. Systems provided in the 1990's strongly resembled systems from the 1960's, in both equipment and architecture, with the exception of certain computer, signal processing and user interface components.

Recent technologies and system innovations have now made it possible to consider radically different system architectures / partitions, fully digital systems and signal processes, new radiations generator concepts, advanced compensation algorithms, highly networked distributed control arrangements, open interfacing standards, and many other functions / features, beneficial to the performance, operation, maintenance and installation of these systems.

This chapter is the second of a two-part discussion concerning the nature of radiation transmission-based strip thickness measurement systems. The previous chapter (Zipf, 2010) examined the fundamental physics, instruments, signal processes, classical system architectures and implementations. This chapter explores the different paths that recent developmental avenues have considered and efforts taken in the advancement of this form of thickness measurement systems. A comparison of classical and contemporary system architectures is examined, followed by a series of focused discussions on recent evolutions in detectors, radiation generators and signal processing / control systems. New highly networked / highly interface-able / distributed system arrangements will be presented, along with methods of multi-system consolidation to minimize equipment and installation requirements.

2. Modern Departures from Classical Systems Architectures

2.1 Classical System Architecture

Figure 2.1 provides a reiteration of the previous chapter's architectural arrangement (Zipf, 2009) and a layout of a typical installation shown in Figure 2.2.

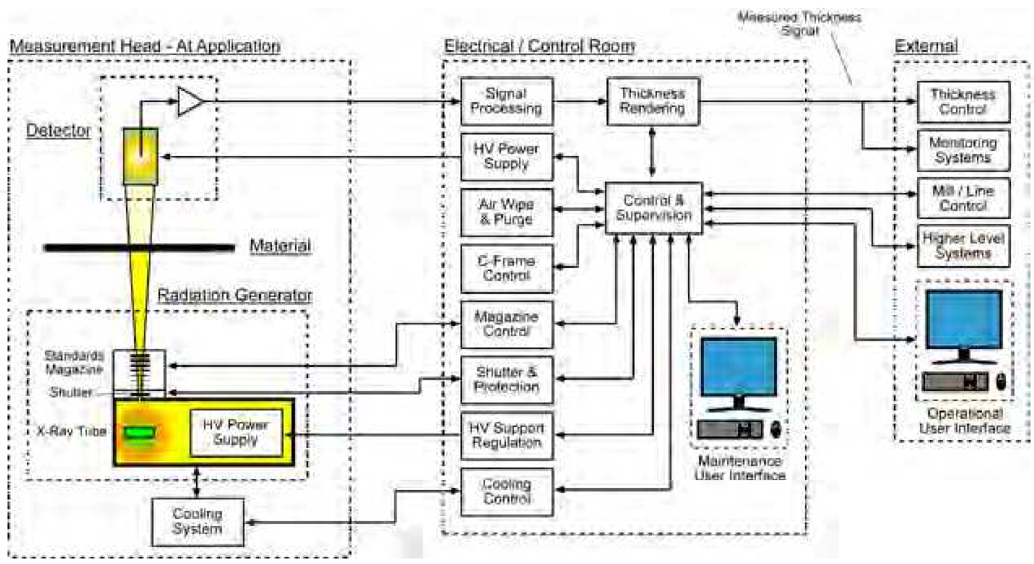


Fig. 2.1 – Classical strip thickness measurement system architecture and organization.

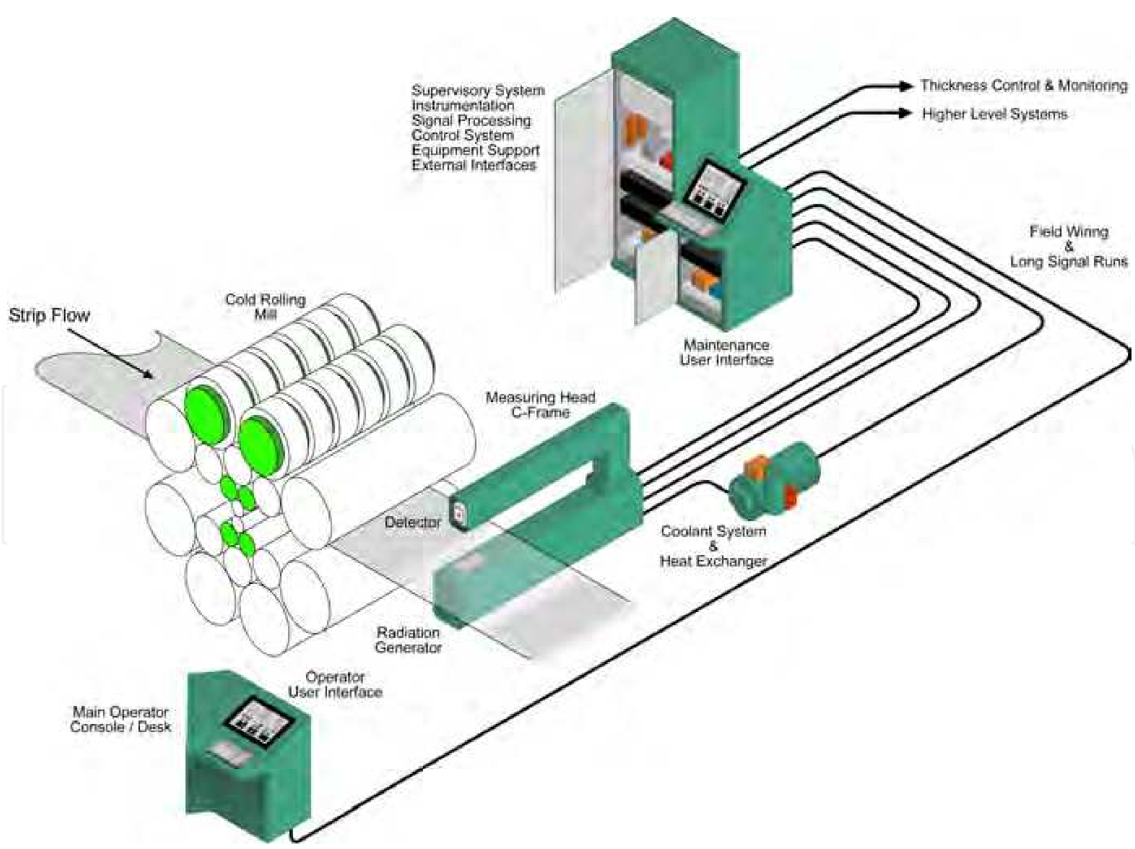


Fig. 2.2 – Layout illustration of a typical strip thickness measurement system installation.

The important architectural factors in the system arrangements of Figures 2.1 and 2.2, are the highly consolidated / highly centralized nature of the system's control, supervision and signal processing components, and its remoteness from the measuring head equipment. Extensive field wiring and long signal runs are an inevitable consequence of this architecture / arrangement in industrial settings. The centralized systems are often very fixed / rigid, and offer no convenient method for expansions of the system capabilities (e.g., additional measuring heads, additional user interfaces, etc.).

This architecture originated in single computer systems, whose processing power was limited and carefully applied to achieve the measurement specifications with fast dynamic responses. Computer equipment technologies were not as robust as we currently enjoy. It was necessary to consolidate / sequester the electronics and computing equipment in environmentally protected / controlled electrical control rooms, distant from the industrial conditions where the measuring head equipment resided. Long field wiring and signal runs were a necessary component of the design and installation. Interfaces to external equipment was typically primitive, employing analog signals (for information bandwidth needs) and low data throughput serial links.

2.2 Traits of Modern System Architectures

The classical system architecture has a number of limitations. Modern electronics, control system equipment and networks have allowed a re-examination of the system organization, and various means of improving the quality of the measurement and transmitted signals. The primary points of interest are:

- Minimization of field wiring and long signal runs
- Maximize noise immunity and information integrity
- Consolidation of critical analog signals and immediate digitization
- High speed, digital signal processing and Field Programmable Gate Array (FPGA) technologies.
- Self-contained, local control of C-Frame equipment
- Numerical thickness measurement rendered at the C-Frame
- Modular organization and distributed control architecture
- Highly networked system interconnects
- Graphical User Interfaces (GUIs) / Human Machine Interfaces (HMIs)
- Fully integrated detector assemblies
- Compact tube / tank assembly
- Passive X-Ray tube thermal dissipation and removal of external cooling systems
- Dry-potted, high voltage power supply (withdrawn from dielectric oil)
- Compact, self-contained X-Ray generators
- Highly interface-able and compliant with network / database standards (OPC, etc.)
- Scalable / expandable (arbitrary number of C-Frames and operator GUIs / HMIs)
- Equipment consolidation through multi-core processors

The basic concepts and objectives of the above list can be achieved by the reorganization of the system architecture of Figure 2.1, and the application of newly available technologies. Figures 2.3 and 2.4 provide illustrations of a contemporary architecture and system organization.

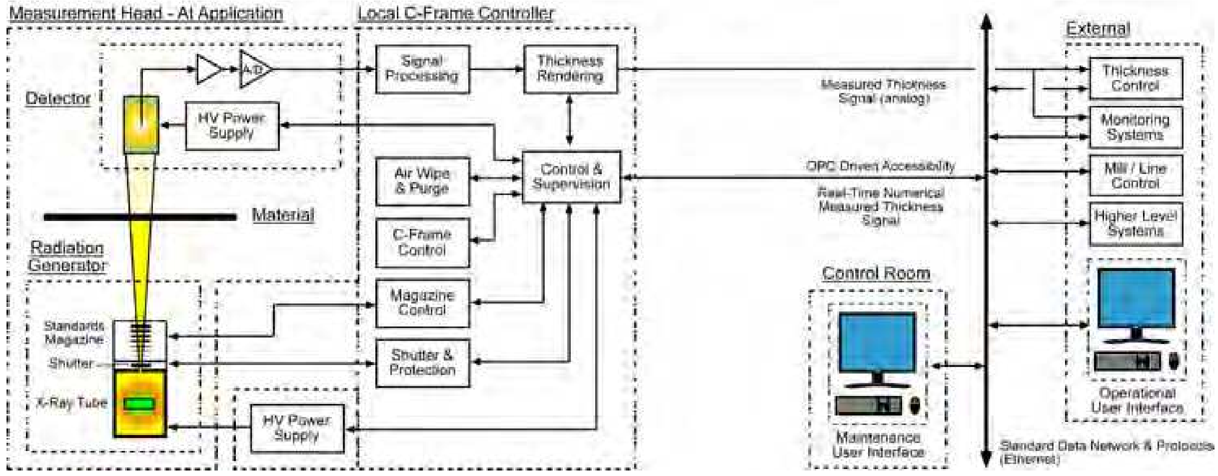


Fig. 2.3 – Desired, contemporary architecture and organization of a modern strip thickness measurement system.

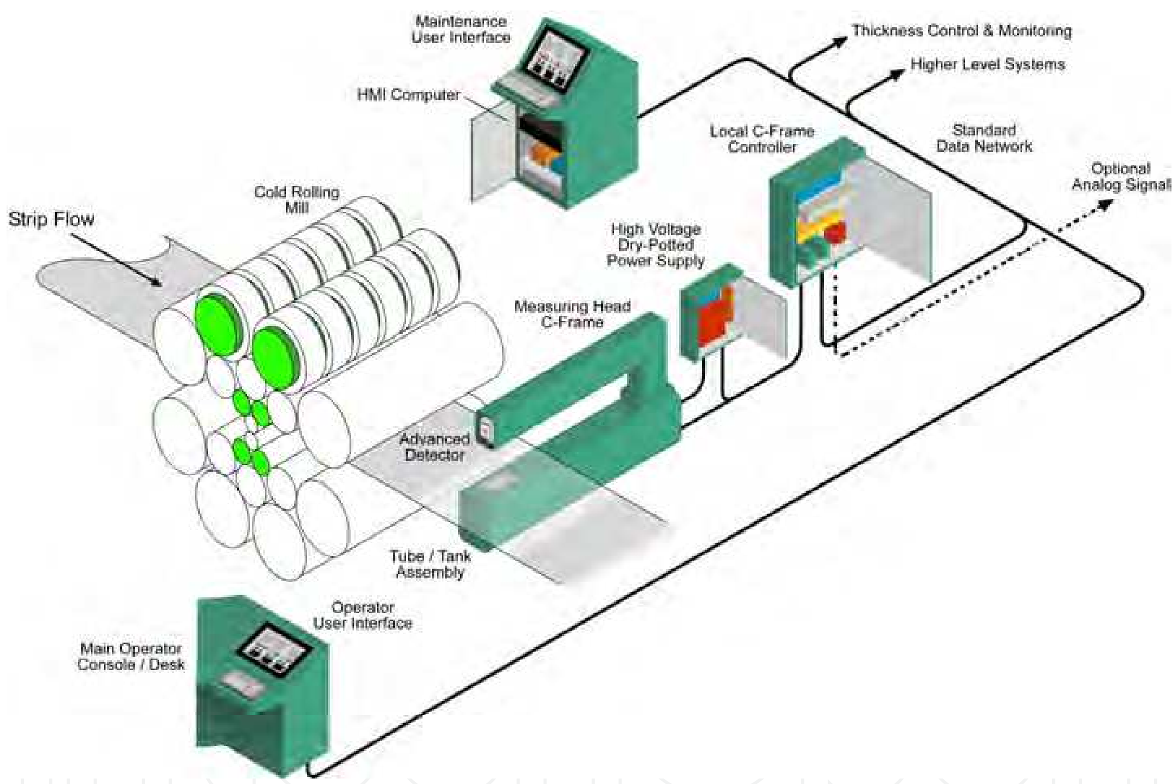


Fig. 2.4 – Layout illustration of a desired, contemporary strip thickness measurement system installation.

The key aspect of the modern system architecture is that what was once a remote, centralized system, is now modular, distributed and localized to the C-Frame / measurement head (Zipf, et. al., 2007a). This consolidation of all control / signal processing (local to the C-Frame / measurement head) allows us to consider the C-Frame equipment as a complete, free-standing system (C-Frame System = C-Frame, HV Power Supply, Local C-Frame Controller). Essentially all other equipment (operator interfaces, GUIs, etc.) are peripheral.

The networked interconnect significantly reduces field wiring, and allows the free-standing C-Frame System to be conveniently integrated into broader industrial applications. The digital / numerical nature of the high speed network data exchanges, eliminates the need for long analog signal runs and provides inherent noise immunity. The distance between system components (e.g., C-Frame System and operator interfaces / GUIs / HMIs) is limited only by the capabilities of the network media (copper wire, fiber optic, etc.). This arrangement is completely scalable / expandable, through direct replication of the C-Frame System and the attachment of additional HMI Computers, as network drops. Figure 2.5 provides a hierarchical view of this form of highly networked system arrangement.

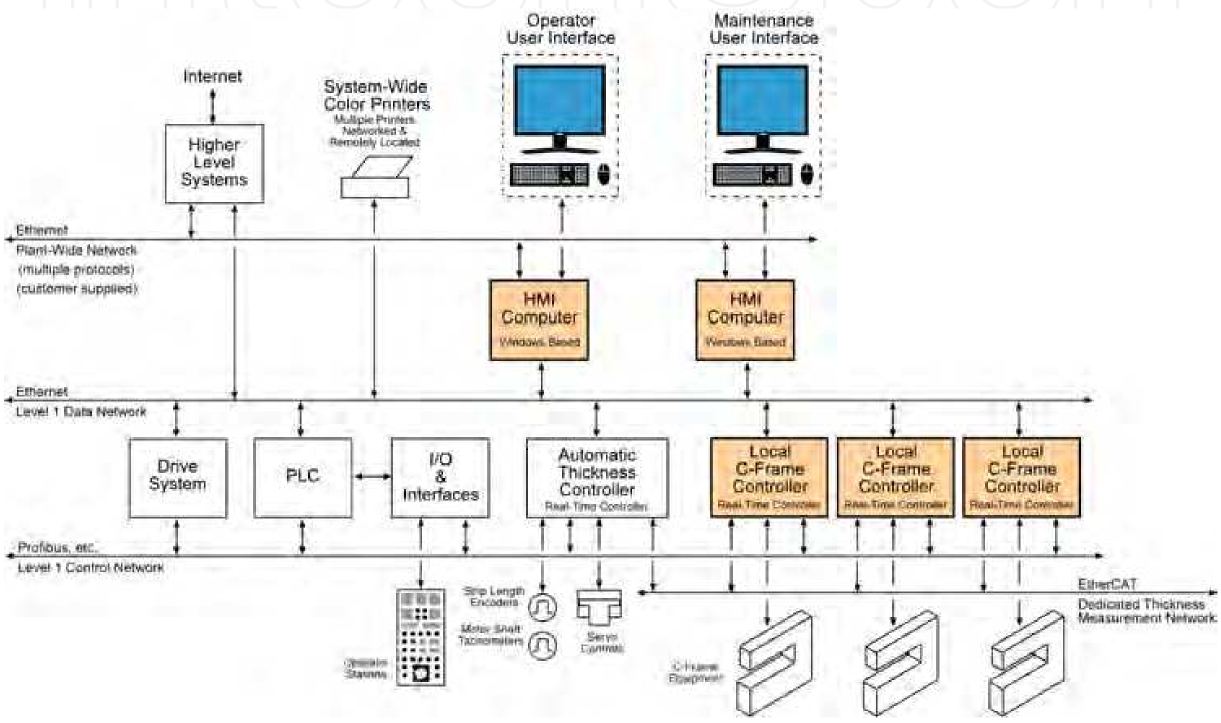


Fig. 2.5 – Hierarchical block diagram illustration of the network topology, components and their interconnections.

An interesting advancement is the Dedicated Thickness Measurement Network (DTMNet). This real-time, deterministic network (EtherCAT, etc.) provides high speed data exchanges (thickness indications and status broadcasts) between the gauging system and the Automatic Thickness / Gauge Control (AGC) system (or other gauge monitoring, quality tracking system). In this way, the separation between equipment is not hampered by noise and interference experienced by long analog signal runs.

The C-Frame Controllers are mounted local to the C-Frame equipment (in industrial / mill duty enclosures) and function as complete stand-alone units, handling and supervising all aspects of the signal processing, control and operation of the measuring head and C-Frame, and rendering a numerical / digital value of the measured thickness local to the C-Frame (Zipf, et. al., 2007a). The controller can interface to surrounding equipment through the Level 1 Control and Data Networks to support commands, status and large data set exchanges. Wide bandwidth thickness measurement data can be transmitted on the deterministic DTMNet, or via analog or serial links (to support legacy systems). The controllers are OPC compliant and can openly publish (allow access to) their entire control / set-up parameter registers for easy integration, remote control and diagnostic support. Advanced Web-based technologies (AJAX, HTML, Java Scripts) allow the controllers to publish real-time graphical and status data to thin client HMI computers, and through directed Internet access (via the higher level systems), remote monitoring capabilities from virtually anywhere, even on mobile phones (iPhone, PDA, etc.) (Zipf, et. al., 2008b).

The maintenance and operator interfaces can be based purely on networked general purpose HMI computers functioning only as thin clients (Internet Explorer, FireFox, Crome, etc.), being supported by / through OPC Servers and the Web-based streaming data from the C-Frame Controllers. Internet-based remote accessibility is possible via network interfaces to the high level systems.

3. Advances in Radiation Detection Systems

Radiation detection systems acquire and measure the intensity of incident radiation, and provide an instrumented signal functionally related to the received radiation intensity. Detectors typically employ either a photomultiplier tube (PMT) in combination with a scintillation crystal (typically Sodium-Iodide) or an ionization chamber (ion chamber) pressurized with appropriate mixtures of ideal and "getter" gases (Zipf, 2009), as the fundamental sensor. Both employ low noise, electrometer class pre-amplifiers mounted local to the sensor, to amplify the detector signal amplitude and provide the necessary line drive to potentially remote signal processing equipment.

In the past, PMT based detectors were favored because of their enhanced speed and sensitivities, unfortunately, this equipment is susceptible to fractures of the scintillation crystal and the PMT dynode chain is inherently delicate and fragile. Historically, ion chambers are of a far more rugged / robust construction and recent advances in ion chamber technologies have allowed them to eclipse PMTs as the preferred radiation detection sensor.

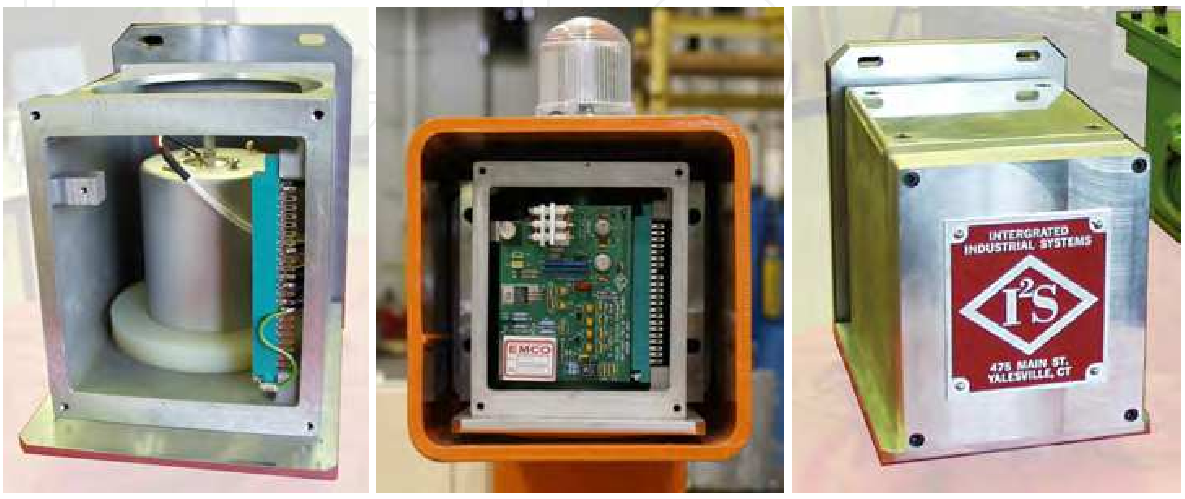
The key recent innovations have come in the following forms:

- Compact, fully integrated detector assemblies
  - Pre-amplifier mounted in detector housing, immediately adjacent to the sensor
  - Programmable high voltage power supply mounted in detector housing
  - Immediate analog-to-digital conversion of pre-amplifier signal
  - Dedicated network interconnect to signal processing system
- Ion chamber arrays
- Solid state / semiconductor sensors

3.1 Compact, Fully Integrated Detector Assemblies

A comparison of Figures 2.1 and 2.3, illustrates the consolidation of the sensor, instrumentation and power supply within the detector housing. The detector is a fully stand-alone unit, capable of supplying high resolution numerical representations of the measured radiation (no analog signal output), requiring only low voltage power, network and air purge connections / cabling.

The sensor (PMT or Ion Chamber) is mounted in a sealed, mill duty, enclosure / housing. The electrometer class pre-amplifier, high voltage power supply, analog-to-digital converter (A/D) and network interface components, are consolidated onto an industrial duty electronics board, mounted within the housing. The entire housing is sealed / submersible and air purged for environmental protection (dust, fluids, grease). Figure 3.1 provides some photos showing a typical detector assembly.



(a) (b) (c)

Fig. 3.1 – Photos of typical detector assemblies: a) Machined monoblock housing containing cylindrical ion chamber sensor, b) Mounted detector assembly with integrated electronics card with sealed cover removed, c) Fully assembled detector.

3.2 Ion Chamber Arrays

There is a fundamental limitation between the extent of the ion chamber's entry aperture and speed of response. Faster responses can be achieved through chamber geometries that minimize the electron drift distances, at the cost of a reduced radiation gathering capability (smaller aperture). The reduction in drift distances reduces the time required for the detector's filament to collect the ionized charge (free electrons), leading to a faster response. The reduction in aperture size can be accommodated by employing multiple, identical, small aperture ion chambers arranged in an array that coincides with the geometry of the received radiation pattern.

The sensor array can be connected in parallel and supported by a single pre-amplifier, or can remain independent, requiring a matching array of pre-amplifiers. Independent pairs of sensors / pre-amplifiers provide the ability to monitor the performance of each sensor, supply downstream signal processing compensation, and evaluate the received beam pattern, all at the cost of added complexity.

Independent pairs also provide the ability to charge each ion chamber differently (different tuned gas mixtures, pressures, voltages and window materials). This offers the ability to detect and compensate for changes in material composition (alloys), and apply the appropriate alloy compensation.

3.3 Solid State / Semiconductor Sensors

Semiconductor sensors (typically in the form of a photodiode), measure the intensity of incident radiation as a function of the number of charge carries (electron / hole pairs) freed within the detector. The electron-hole pair formation energy is relatively low, when compared to the production of ions in gas detectors, making the inherent sensitivity / resolution higher. The time resolution is also very good and cooling systems (typically thermo-electric) can reduce the sensor's thermal noise to improve low radiation level performance. Their small size makes them ideal for high resolution area arrays, which can be used for beam geometry, uniformity and alignment studies.

However, the dynamic range of these typically silicon detectors can be limited and their relatively small size makes it difficult to over-contain the inbound radiation beam. They also suffer from performance degradation from long exposure to radiation.

4. Evolution of Radiation Generators

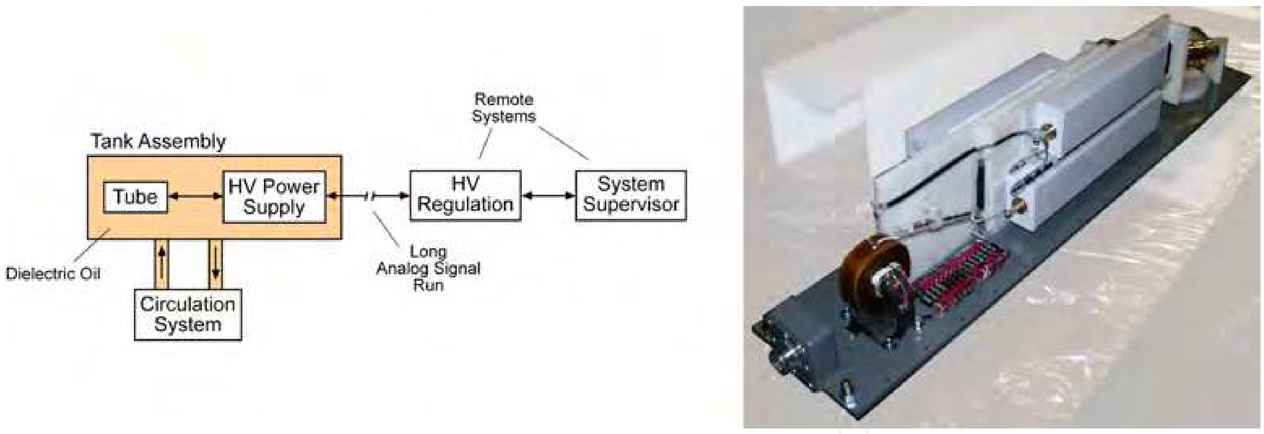
X-Ray radiation generation techniques have experienced a number of key innovations over the last few years. These developments have allowed for totally new system architectures to be made available, along with improvements in the maintainability of this equipment.

4.1 Classical X-Ray Generators

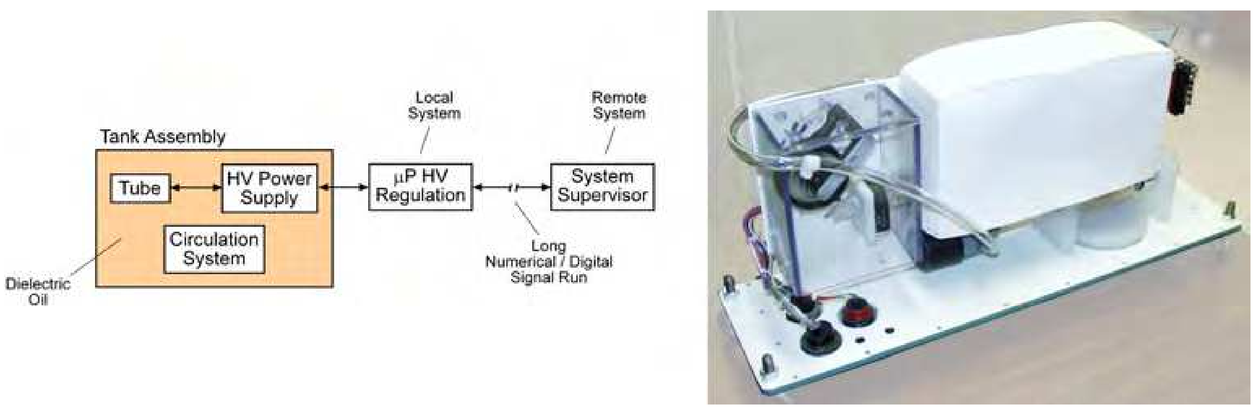
Classical / legacy X-Ray generation systems employ large, heavy, shielded tank assemblies containing the X-Ray tube and high voltage power supply, all immersed in a bath of dielectric oil. These assemblies are not only large, but also very heavy (often greater than 125 kg due to the large amount of lead shielding required) and difficult to extract from the C-Frame (often requiring several people). The high voltage power supplies are regularly driven, controlled and regulated by remote / external analog electronics. These arrangements often suffer from the limitations of long signal runs and the natural perturbations of discrete analog circuitry, inducing questionable accuracies and drifting characteristics. The oil is often circulated through external cooling systems (outside the C-Frame structure), requiring a mix of flexible and fixed tubing, pumps, filters, heat exchangers, etc. Leaks in these coolant loops could disable or damage the generators, induce uncompensated thermal variations in the produced radiation, or over-pressure the tank / fluid system by the oil's thermal expansion. Figure 4.1a provides a block diagram and photograph of typical internal components associated with this system arrangement.

4.2 Sealed X-Ray Generators and Local Regulation

A developmental step forward involved sealed, fully contained tank assemblies that did not require external cooling systems. This approach utilized high integrity, internal circulation systems and relied on the tank structure's heat dissipation characteristics to provide the necessary thermal relief. Careful design considerations were required to ensure that the necessary heat dissipation was provided, however the removal of the external coolant systems was a welcome advancement. Figure 4.1b provides a block diagram description and photograph of typical internal components associated with this system arrangement.



(a)



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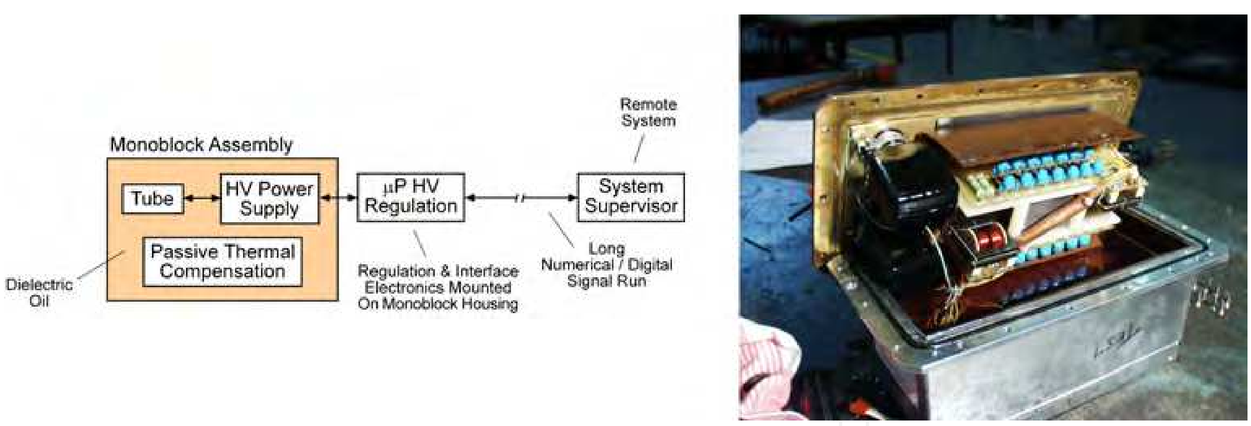


(c)

Fig. 4.1 – Diagrams and photos illustrating various avenues of X-Ray generator development: a) Classical generator arrangement using an external cooling system and the high voltage components immersed in dielectric oil, b) Development of internal circulation and thermal dissipation techniques to provide a more self-contained and reliable operation. This diagram also shows the employment of microprocessor based regulation and interfacing mounted local to the tank assembly and high voltage power supply, c) Ultra-compact monoblock arrangement using passive thermal compensation.

Another advancement involved the development of localized, computer controlled and regulated high voltage power supplies. Here, the high voltage electronics and drive circuitry was located within the oil immersed tank and microprocessor based controllers were mounted in environmentally protected enclosures within the C-Frame. Digital fiber optic communication links were provided to set and monitor the high voltage systems, and to provide inherent isolation to the supervisory and signal processing equipment. This step provided the removal of remote analog electronic drive systems and provided higher system accuracies due to the tighter radiation regulation. However, this arrangement still relied on an internal oil circulation system, and still required a relatively large and heavy tank assembly.

4.3 Compact Monoblock X-Ray Generators

There has been a long standing interest in finding X-Ray based direct replacements for existing isotope sources (Zipf, et. al., 2007b). Isotope sources require special handling and maintenance considerations, and by their fundamental nature, can not be “turned-off”. The idea has been to create a highly compact, fully self-contained X-Ray generator, whose physical size matches that of the isotope source housing, provides the necessary radiation intensity and can internally compensate for the X-Ray tube’s thermal dissipation needs. Ideally, this compact X-Ray generator would be directly retrofit-able to existing isotope source installations, requiring only minor modifications to support the new equipment, and it would also provide a wide range of interfacing possibilities, to support the broad spectrum of existing isotope based systems and instrumentation.

The development of monoblock systems directly addresses these needs by employing a small format X-Ray tube, compact programmable high voltage power supply, passive thermal dissipation methods and externally / adjacently mounted regulation and interface electronics, all within a sufficiently small physical size that it can reside in the available C-Frame space of existing isotope radiation sources (Zipf, et. al., 2007). Figure 4.1b provides a block diagram and photograph of a typical compact, monoblock assembly.

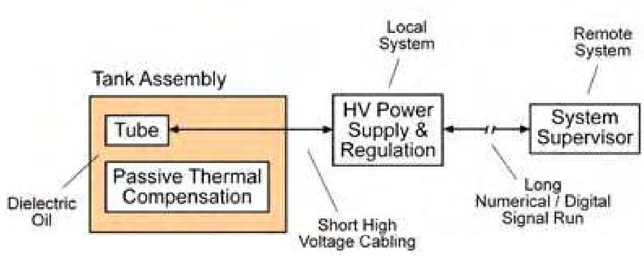
An important innovation can be seen in the passive thermal compensation technique used in the limited volume of dielectric oil and relatively small cooling surfaces. The idea is to employ internal air bladders that vent to ambient (external to the tank), located within the tank assembly. As the tube’s thermal conditions expand the dielectric oil, the bladders volumetrically deflate to absorb / compensate for the oil’s expanded volume, and maintain a non-pressurized tank (Zipf, et. al., 2007b).

The monoblock units include a localized microprocessor based controller that oversees, controls and regulates that generator’s operations. This controller provides a variety of interfacing possibilities (network, serial, discrete signal, etc.) and the ability to report detailed status and performance information. This allows this unit to be installed in many existing isotope-based systems with only minor instrumentation / interfacing modifications.

These monoblock concepts stem from the existing technologies employed in the medical instrumentation and inspection industries, but have not been considered (until recently) in the harsh environments associated with industrial and mill duty settings. These systems are gaining popularity even in the presence of their non-trivial costs.

4.4 Dry-Potted High Voltage Power Supplies and Compact Tube / Tank Assemblies

An important innovation came with the development of modular, dry, potted high voltage systems mounted external to the tank assembly, but local to the C-Frame, and capable of supporting X-Ray tube potentials ranging from 10kV to 150kV (Zipf, et. al., 2008b). This is a major advancement in that the only component required within the oil immersion tank was the X-Ray tube itself. High voltage is supplied to the tube by protected, flexible high voltage cabling / connectors. The potted high voltage equipment has a compact format, and mounted in an environmentally sealed industrial enclosure located on or near the C-Frame equipment. The drive and regulation systems are also contained within this enclosure and communicate with the supervisory system via a fiber optic link (to provide further isolation and noise immunity). Figure 4.2 provides a block diagram description and photograph showing the internal components associated with this system's arrangement.



(a)

(b)

Fig. 4.2 – Illustrations of X-Ray radiation generation equipment employing a compact tube / tank arrangement and external, modular, dry, potted high voltage system: a) Block diagram of the typical components and the interconnects / relations, b) Photograph of the dry, potted high voltage bipolar power supply and fiber optic interface controller housed in an environmentally secure enclosure.

This created a modular arrangement that was not only easy to maintain, but the tube / tank assembly now only contained the X-Ray tube and its mounting structures. To reduce the tube's thermal loading on the dielectric oil expansion, the beam current can be reduced to levels on the order of 500 micro-amperes, providing lower operating power (temperature) and longer tube life. This reduction in radiation intensity is countered by an increase in detector sensitivity through proper design and manufacture of the sensors, along with lower noise pre-amplifier electronics.

The thermal loading / expansion of the dielectric oil is thereby minimized, and can be accommodated by the passive expansion / dissipation methods (internally mounted air bladders) described in Section 4.3 used in the monoblock generators. The tube / tank assembly was now of a size, form factor and weight that permitted handling by a single person (tube tank assembly weights on the order of 20-30 kg, directly accessible from the front / operator-side of the C-Frame). Figure 4.3 provides photographs of a typical tube / tank assembly.

(a)

(b)

Fig. 4.3 – Photographs showing a typical tube / tank assembly: a) Tube / tank assembly and standards magazine (top) withdrawn from the base of a C-Frame, b) Internal components of the sealed tube / tank assembly, showing the shielded, insulated dielectric oil tank and air bladders (left), and X-Ray tube mounted to the tank lid (right).

5. Advances in Signal Processing and Control

One of the major system architecture advancements has been to partition, distribute and decentralize the operational responsibilities, by localizing the signal processing and control to the C-Frame / measurement head areas. This work has followed three (3) primary objectives:

- Complete, independent control and supervision of an individual C-Frame's systems with a localized real-time controller
- Calibrated, real-time indications of the measured thickness local to the C-Frame via high speed digital signal processing (DSP) hardware and algorithms
- Fully networked, high speed communications for command and status data exchanges, and distribute deterministic numerical thickness measurements over a dedicated network.

5.1 C-Frame Controller

In the past, locating commercially available control system equipment in harsh, mill duty environments was not an appropriate option. The physical size and required support equipment made them too awkward to consider in this application.

Recent developments in off-the-shelf, industrial controller technologies, not only provide compact physical arrangements, suitable for mill duty industrial applications, but also offer high speed real-time processing and embedded Field Programmable Gate Array (FPGA) circuitry, allowing them to tackle exceedingly fast signal processing and control problems. One such family of devices is the National Instruments Compact Remote I/O (cRIO) Programmable Automation Controllers (PACs), which offer high resolution interfacing, full network compatibility and a flexible framework from which a variety of applications can be accommodated. The PAC contains a programmable CPU running a real-time operating system (RTOS) (Wisti, et. al, 2008) and an underlying programmable FPGA hardware layer

(NI, 2007a,b). Both components are programmed with National Instrument's LabView language and the target code is stored in onboard Flash memory.

A PAC controller and associated support equipment reside in an environmentally protected enclosure, located in direct proximity to an individual C-Frame / measurement head. Figures 5.1 and 5.2 illustrate this system arrangement. The controller's responsibilities are partitioned between the real-time processor and FPGA hardware.

> FPGA Hardware – This hardware is programmed to receive the digitized, pre-amplifier measurement of the detector's sensor (from the A/D) and perform the selected digital signals processing (DSP) algorithms (see Figure 6.1 of Zipf, 2009) to immediately render a calibrated thickness measurement. The resulting measurement can be output as a high resolution analog signal (to support legacy systems) or passed to the RTOS for distribution over the DTMNet. The signal processing parameters / calibration coefficients are provided by the RTOS and openly accessible via the OPC interface.

> Real-Time CPU / RTOS - This processor is responsible for all C-Frame equipment control and operational activities including: Closed-loop C-Frame motion control, high voltage power supply supervision, air wipe / purge systems, magazine and shutter control, calibration and standardization, safety and protection systems. This processor manages all network interfaces (Level 1 Data Network and DTMNet) and supports the OPC Server interface. All calibration, alloy compensation and signal processing parameters are handled by this processor and distributed on the OPC interface, to maximize interface-ability, remote control, performance monitoring and diagnostic support. This processor also employs advanced Web-based technologies (AJAX, HTML, Java Scripts) to allow publishing of real-time graphical and status data to thin client HMI computers, and through directed Internet access (via the higher level systems), remote monitoring capabilities.

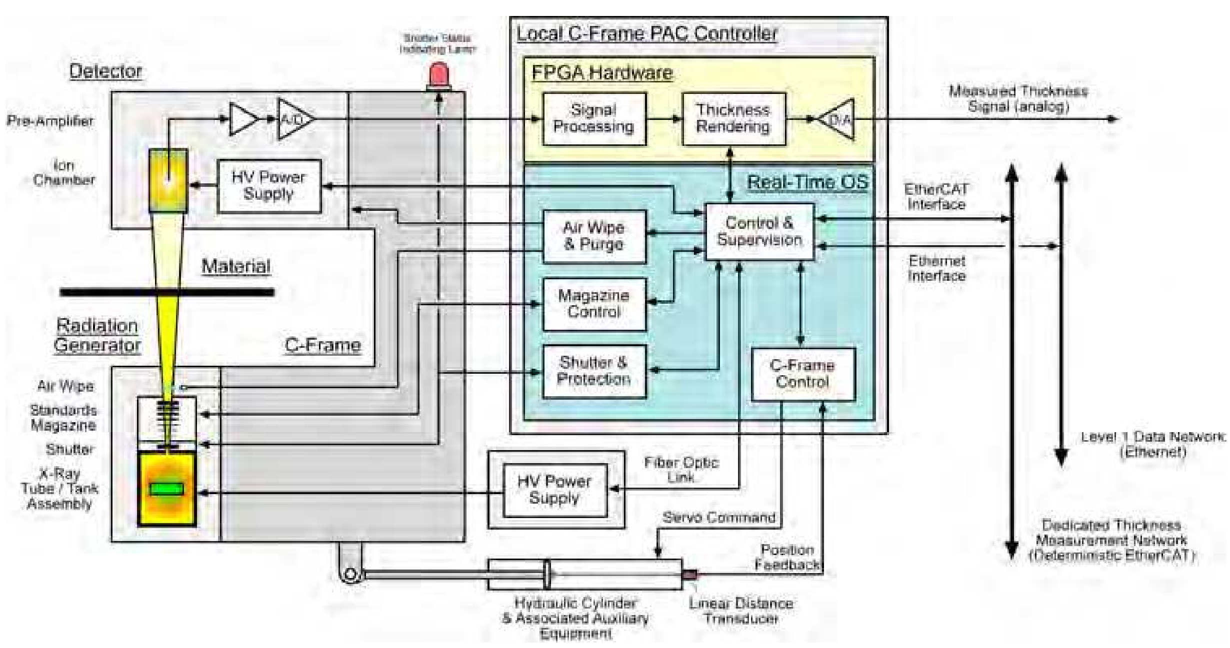


Fig. 5.1 – Block diagram showing the C-Frame Controller, the internal partitions between the RTOS and the FPGA hardware, and the internal and external interconnections.

(a) (b)

Fig. 5.2 – Photographs showing the C-Frame PAC Controller: a) National Instruments cRIO PAC, b) C-Frame Controller and associated support equipment, mounted in a environmental protection enclosure.

5.2 User and External System Interfacing

The highly networked nature of the system architecture (Figure 2.5) and the C-Frame Controllers provide a number of opportunities for interfacing and scalability / expansion. The popularity and commonplace of OPC Server technologies allows extensive availability of the C-Frame Controller's internal parameters, high voltage and detector calibration data, command and control structures, collected data buffers, performance and status data, etc. This broad and selectable exposure of OPC Tags allows the C-Frame Controller to be easily integrated into complex automation systems, and externally controlled / tuned to match the needs of the application and process.

The networked architecture also provides the ability to support sophisticated, fast responding Web-based GUIs (AJAX, HTML, Java Scripts), arbitrarily added as thin client drops via general purpose HMI Computers (Zipf, et. al., 2008b). These GUIs interact through the database provided within the OPC Server and through data streaming methods, to provide real-time graphics and visualizations. Through higher level system interfaces to the Internet, remote control, monitoring and diagnostic assistance can be provided from any Internet access point, world-wide. The extensive OPC interfacing allows for the use of commercially available (off-the-shelf) software packages (e.g., Siemens WinCC, GE Cimplicity, Intellution, Wonder Ware, Interact X, RS View, etc.) to also implement operator and maintenance interface GUIs.

The networked interfacing also provides a substantial reduction in the extent of field wiring required to support the overall thickness measurement system, and has a direct impact on the installation activities. Only low voltage AC power, Ethernet cable, EtherCAT cable and E-Stop wiring are required.

6. System Consolidation Using Multi-Processor Technologies

An interesting side-line of the modern architectural arrangement and implementation (Figures 2.3, 2.4 and 2.5), is the ability to consolidate multiple related systems into a single computer arrangement, through the use of multi-processor technologies. The main driving force behind this interest stems from a desire to minimize and hyper-modularize multiple system equipment, primarily to support surgical modernization, replacement and retrofit efforts of older or obsolete equipment. The idea is to be able to replace older multi-computer systems with a single, modern, multi-processor based system.

6.1 Industrial Case Study

An interesting industrial case study can be found in the thickness measurement and control systems found in cold rolling mills. A classical system arrangement is shown in Figure 6.1.

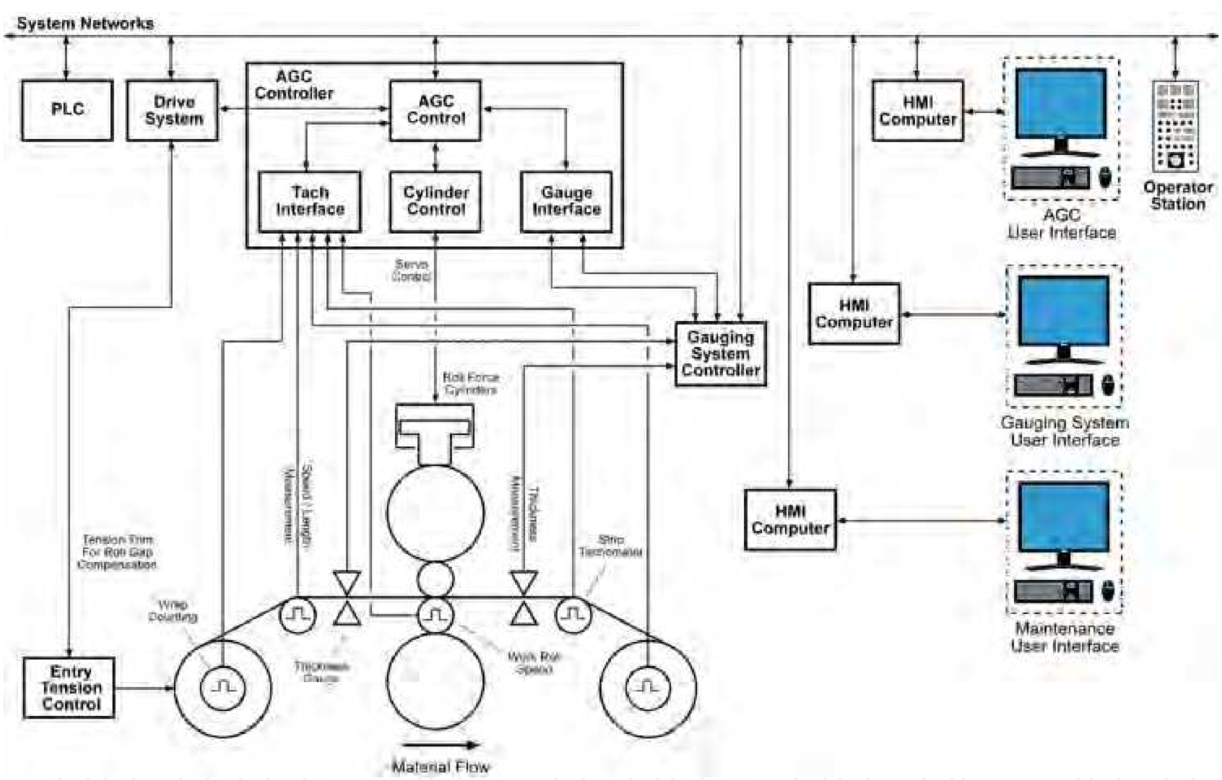


Fig. 6.1 – General arrangement and primary components associated with strip thickness measurement and control, in a cold rolling mill application.

The overall mill systems and operations are controlled / coordinated through the master programmable logic controller (PLC). A motor drive system provides strip transport and tension control. Strip thickness is measured on the entry and exit sides of the mill, and provided to the thickness controller. The thickness controller (AGC) adjusts the compressive roll force and trims the entry tension to provide corrections to the rolled material thickness. The operator controls and indications for the AGC and gauging system are provided through operator station control hardware and metering, while HMI Computers support interactive GUIs. A maintenance / engineering interface is provided to developmental support of the PLC, drive systems, AGC and gauging systems.

This system often consists of a five (5) computer arrangement, integrated into the general mill and drive system controls.

- AGC Real-Time Controller
- AGC HMI Computer
- Gauging System Controller
- Gauging System HMI Computer
- Maintenance Support HMI Computer

Through the use of similar FPGA, RTOS and Multi-Core Processor technologies (Wisti, et. al., 2008) (Zipf, et. al., 2008a), AGC Systems have been reduced to single computer arrangements. Here, using an Intel Dual Core processor, one core (running VxWorks) is dedicated to the real-time activities of the AGC Controller, while the other core (running Windows XP) handles the AGC's HMI tasks and supports the onboard OPC Server.

An extension of this concept involves the integration of the AGC, Gauging System, OPC Server, all HMI's and Maintenance Support into a single computer system. Development is currently underway, with the idea of employing an Intel Quad Core processor and a pair of self-contained C-Frame Controllers to achieve this consolidation. Figure 6.2 provides a block diagram illustration of this system arrangement, with the following core allocation:

- Core 1 : AGC Real-Time Controller running VxWorks
- Core 2 : AGC HMI and OPC Server running Windows XP
- Core 3 : Gauging System HMI running Windows XP
- Core 4 : Maintenance, Support and Development Software running Windows XP

The pair of C-Frame Controllers interface to the AGC Controller via a DTMNet and to the OPC Server and HMI via the Level 1 Data Network.

The first of these highly consolidated, multi-core processor systems is expected to be deployed in the mid-2010 time frame.

7. Conclusion

This chapter has presented a number of avenues of development and evolution in radiation based thickness measurement systems. The classical system architecture was reviewed and compared against various versions of contemporary architectures. It was shown that advancements in network systems have allowed highly decentralized / distributed configurations to be implemented, with a concentration of control / supervision authority local to the C-Frame / measurement head.

Detector developments have centered mainly on the full integration of all components into the sealed detector housing, and the inclusion of immediate digitization with deterministic networked distribution. These compact, self-contained detector assemblies offer convenient maintenance and easy spare / repair actions.

Developments in radiation generators have been interesting and varied. On one side, compact monoblock assemblies using passive thermal compensation and onboard regulation, control and supervision, offer opportunities to replace existing isotope sources.

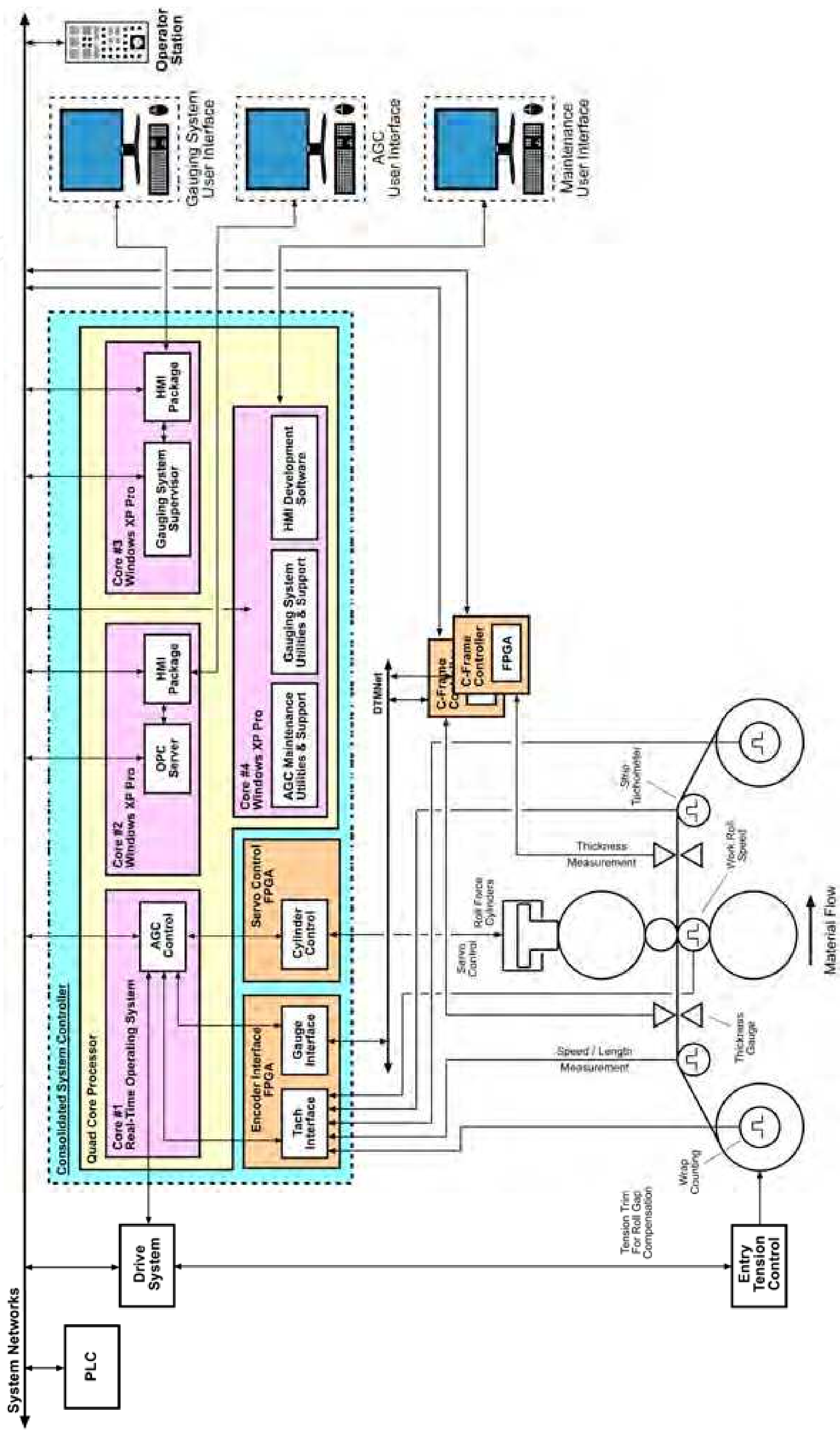


Fig. 6.2 – Block diagram showing a highly consolidated system, employing multi-core technologies, real-time controls, FPGA signal processing and networked interconnects.

On the other side, dry-potted, programmable high voltage power supplies provide an improving degree of modularity and require that only the X-Ray tube be immersed in oil, making it possible to use compact tube / tank assemblies that can be handled by a single person. The compact tube / tank assembly offers convenient maintenance and easy spare / repair actions.

New processor and FPGA technologies have allowed advanced real-time control, signal processing and complex analytic compensation to be performed local to the C-Frame / measurement head. Highly networked, distributed architectures eliminate long analog signal runs, offer broad interface-ability and flexible scaling / expansion. Advanced Web-based technologies coupled with OPC Servers provide the ability to support highly interactive, fast responding GUIs via thin clients executing on general purpose HMI Computers. Further, these methods provide Internet accessibility for remote control, monitoring and diagnostic assistance from any access point, world-wide.

Multi-core processor technologies have opened a new developmental avenue by offering the ability to consolidate multi-computer systems into single computer frameworks. These concepts provide new opportunities for surgical replacement / modernization of aged, obsolete equipment and reductions in installation costs and production outages.

In closing, it's rather interesting to note the various twists and turns in the developmental evolution of these systems. On one side, there is a consuming interest in decentralization, modular independence of subsystems and distribution of control / supervision local to the application. On the other side, new processor technologies draw developers to consolidate multi-computer systems into single computer arrangements. It would appear that the future may embrace the philosophy of decentralized consolidation employing integrated modularity.

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